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NOTE ON RIEFLER CLOCK.

The new Riefler clock delivered to the observatory in the fall of 1906, and started in late November, differs from the rest of the observatory clocks in three essential particulars,—namely, in having a nickel-steel, compensated pendulum, in the construction and operation of its motive apparatus, and in its arrangement for constant pressure.

The first of these differences gives a metallic bar pendulum instead of the usual mercury pendulum. This becomes possible through the invention of a combination of nickel and steel, the coefficient of expansion of which is exceedingly small.

The arrangement for supplying the motive power shows the greatest departure from old lines. Three Edison-Lalande cells, connected in series and regulated by a rheostat, supply the power for lifting the driving weight of the clock. This weight, about ten grams, is pivoted at one end, and at the other engages, with a pawl, a wheel directly connected with what is known as the third wheel in clocks of the ordinary winding devices. When the weight has finished its fall, it completes the battery circuit and is lifted again by an electromagnetic lever. The relation between the weight lifted and the strength of the battery is such that the intervals between lifts may vary from 28^s to 34^s. If it becomes less than 28^s, a little falling off in battery strength will result in failure to wind. Since it can fall from the highest possible position in 34^s, any attempt to increase the battery strength beyond the amount necessary to raise it to this point only produces a violent contact at the top of its lift. A daily note of this interval gives a check on the battery strength and a warning when to lessen the resistance in the rheostat. The device works very smoothly.

To secure a constant pressure, the entire clock is mounted inside a heavy cylindrical glass case consisting of two parts, the perfect sealing of which is secured by ground-glass surfaces coated with vaseline.

Between December 1, 1906, and the latter half of June, 1907, the clock ran for several short periods under such varying conditions that no results of value could be obtained therefrom. The clock was finally started, sealed, and the air pressure reduced to 560^{mm}, in the latter half of June, 1907. The

mean yearly pressure at Mt. Hamilton is about 650^{mm} , with a range of $\pm 13^{\text{mm}}$; so that 560^{mm} , being 90^{mm} less than normal, is safely below any possible outside pressure.

At present the clock is mounted in a small fireproof room fitted with double doors, in the basement of the Meridian Circle House. There is no other provision for constant temperature, and therefore the pressure varies within the glass case with variations of temperature. But since the effect of outside temperature is felt only gradually inside the case, the pressure varies in a correspondingly gradual and progressive way, never falling precipitously, as is the case outside just preceding a storm.

All the data gathered since the clock was completely fitted up and started, in June, 1907, has been carefully gone over, giving a full six months' uninterrupted rate. These rates were derived from observations for clock correction with the Meridian Circle, either in connection with some current programme or from especially prepared lists. Up to September 4th, Dent sidereal clock, numbered No. 4 in our series, was used for a standard, with which all the other sidereal as well as mean-time clocks were compared daily. During this period the rates derived for No. 5, the Riefler, were from corrections of either the same or but slightly later epochs. After September 4th, owing to an unsatisfactory fluctuation in the rate of No. 4, No. 5 was substituted, so that during the rest of the period its rates are derived directly from observations. Clock errors during the six months from June, 1907, to January, 1908, were derived from observations on an average of every six days, and, except for one interval of seventeen days, were quite uniformly distributed.

During the same interval the average temperature was $54^{\circ}.8$ F., with an average range of 3° for the intervals between which clock corrections were derived. The maximum for the period was $+64^{\circ}$ F., in August, 1907, and the minimum $+42^{\circ}$ F., in December, 1907. It would have been better, had a whole year of observations been available, for at present data can be used only during a period from maximum to minimum temperature. A complete year would also have given the reverse condition as temperature went from minimum to maximum again. During December, 1906, when the clock was first started, the thermometer went as low as

+ 35° F.; giving a range of 29° for the year against 22° for the six months used. At that time, however, the clock was exposed more than usual, while being adjusted, and temperatures outside were unusually low, also.

A plot of the rate during this period, together with a plot of temperature and barometer range during the same period, show quite exact agreement. Whether this rate change is due directly to temperature effect on the pendulum, or indirectly through its effect on pressure, or to both, is as yet uncertain. It would be possible to test the direct effect of temperature, if the pressure were watched carefully, and kept constant by admitting more air or pumping out, as circumstances required.

However, it is possible to arrive at the variation in clock rate and barometric change concurrent with temperature variations. Readings of the thermometer are made to the nearest degree and of the barometer to the nearest millimeter. A least-square solution of the data gives + 1.3^{mm} as the change in barometer per degree Fahrenheit. This, when applied to the barometric readings, gives an average residual of $\pm 0.73^{\text{mm}}$, which is about one ninth of the average residual for uncorrected readings of the barometer. CHARLES'S law states that the pressure of a gas, of constant volume, varies directly as the absolute temperature. At the pressure here considered the variation of pressure per degree Fahrenheit amounts theoretically to + 1.1^{mm}. This, taken in connection with an observed change of + 1.3^{mm} per degree Fahrenheit, shows that the sealing of the glass chamber is quite satisfactory.

The average rate for No. 5 for the period was $-0^{\text{s}}.165$ per day, with an average residual of $\pm 0^{\text{s}}.089$. The smallest was $0^{\text{s}}.00$, in August, 1907, at a temperature of + 61° 6 F., and the largest $-0^{\text{s}}.37$, in December, 1907, at a temperature of + 42° 8 F. From the plot, mentioned before, it was evident that a change of rate accompanied a change of temperature. A least-square solution for this variation gave + $0^{\text{s}}.016$ per degree Fahrenheit. When the rate is corrected for temperature, the average residual is $\pm 0^{\text{s}}.042$, as compared with $\pm 0^{\text{s}}.089$, the average residual for observed rates.

The rates for the two Höhwu sidereal clocks, numbered No. 3 and No. 8 in our series, have been derived from comparisons with the standard sidereal clocks at epochs corresponding to

those used for the Riefler. During this period the residual from the mean rate was more than twice as large as usual, being $\pm 0^s.29$ and $\pm 0^s.32$ respectively. A change of rate of 1^s in that time was quite apparent in both clocks. When a change of rate of $+0^s.04$ for No. 3 and $-0^s.04$ for No. 8 per interval between which clock corrections were obtained, is applied to these rates, the average residuals are reduced to $\pm 0^s.14$ in both cases. Previous investigation has failed to connect changes in the rates of these clocks with temperature variations, and the fact that in the present instance the changes of rate of the two, while numerically the same, are of opposite signs, leads to the same conclusion. These clocks are mounted in the clock-room, with no particular protection from changes of temperature in the room.

Dent sidereal clock, until September 4, 1907, used almost exclusively for a standard upon which to base the others, has been recently investigated by Professor TUCKER in connection with some of his fundamental work. He is quoted as follows:—

“The Dent clock is inclosed in a small chamber built into the clock-room, and is protected by double doors from changes of temperature in the larger room. The daily change of temperature in the clock rarely amounts to more than one degree, and is usually progressive for periods of considerable length.

“The total variation in a year averages 34° , from 40° to 77° F. being the extreme range on record. During the periods of about one week, into which the tabulation of corrections is divided, the average change is less than 4° . The maximum falls in August, the minimum in December, and the mean temperatures occur in June and October. The yearly mean is close to 58° .

“The variation in the rate of the clock has a well-established connection with the change in temperature, which has generally been reckoned at $+0^s.04$ for a rise in temperature of one degree. For a period of seven months, in 1907, March to September inclusive, the change of $+0^s.03$ has recently been derived, by least-square solution. The application of this temperature correction to the rate results in reducing the average residual for the weekly intervals from $\pm 0^s.21$ to $\pm 0^s.11$, for the seven months. The clock retained a consistent rate during this period, which shows the Dent at perhaps

its best performance. Preceding and following this period, the rate of the clock made abrupt changes."

Taking into consideration this somewhat erratic action on the part of the Dent, and the highly satisfactory way in which the Riefler has been performing, its arrival was timely.

Thanks are due to Professor TUCKER for aid in preparing this note.

R. F. SANFORD.

Mt. HAMILTON, CAL., January 23, 1908.

THE ECLIPSE OF JANUARY 3, 1908.

Before this number of the *Publications* goes to press, I take pleasure in announcing that the total solar eclipse of January 3, 1908, was observed successfully by the Crocker Expedition from the Lick Observatory, University of California, and by the expedition of the Astrophysical Observatory, Smithsonian Institution. The united expeditions were landed on Flint Island on December 9th by the U. S. gunboat "Annapolis," in command of His Excellency C. B. T. MOORE, U. S. Navy, Governor of Tutuila. An observing site was selected in the midst of the cocoanut-trees, and preparations proceeded rapidly, notwithstanding the tropical heat and the multitudes of showers. Every arrangement for securing the observations during totality was completed in good time.

The forenoon of January 3d was alternately clear and cloudy, with the clearness much in excess. About ten minutes before the eclipse was total, clouds formed rapidly, until the sky was densely covered. Just as the time-keeper called from his chronometer, "Five minutes before totality," a drenching rain fell, and all seemed lost save honor. At the end of two or three minutes the rainfall began to decrease and the clouds in the east gave signs of breaking. Less than a minute before totality the slender crescent of the Sun showed faintly through the clouds, though a moderate rain was still falling. The rain and clouds grew rapidly lighter, and the last drops fell at two or three seconds after totality began. Immediately after the beginning of totality the corona was faintly visible through the thin clouds. These continued to disperse rapidly. During the second quarter of the total phase the clouds were extremely thin, and during the third and fourth quarters the sky was essentially clear.